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(74) Agent: **MURGITROYD & COMPANY**; Scotland
House, 165-169 Scotland Street, Glasgow G5 8PL (GB).

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(71) Applicant (*for all designated States except US*): **PUR-SUIT DYNAMICS PLC** [GB/GB]; Shackleton House, Kingfisher Way, Hinchingsbrooke Business Park, Huntingdon, PE29 6HB (GB).

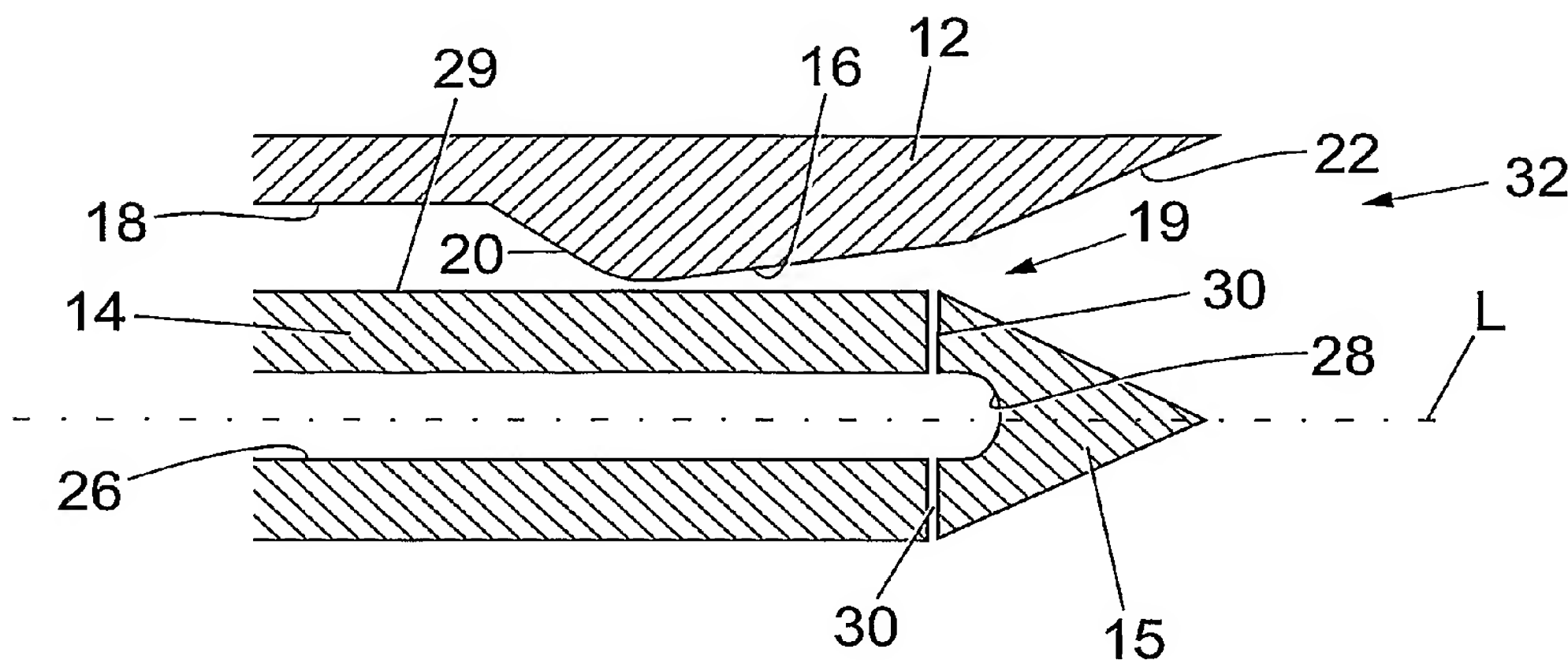
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(72) Inventors; and

(75) Inventors/Applicants (*for US only*): **FENTON, Marcus, Brian, Mayhall** [GB/GB]; 2 Bushmead Road, Eaton Socon, St Neots, Cambridgeshire PE19 8BP (GB). **WALLIS, Alexander, Guy** [GB/AU]; 19 Martlesham Crescent, Colonel Light Gardens, South Australia, 5041 (AU).

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(54) Title: AN IMPROVED MIST GENERATING APPARATUS AND METHOD



(57) Abstract: An apparatus for generating a mist is disclosed, the apparatus having an elongate hollow body (12) and an elongate member (14) located within the body (12). A transport fluid passage (16) and a nozzle (32) are defined between the body (12) and the elongate member (14). The transport fluid passage (16) has a throat portion of reduced cross-sectional area and is in fluid communication with the nozzle (32). The elongate member 14 includes a working fluid passage (26) and one or more communicating bores (30) extending radially outward from the working fluid passage (26). The bores (30) permit a working fluid (e.g. water) to be passed into the transport fluid passage (16), whereupon the working fluid is subjected to shear forces by a high velocity transport fluid (e.g. steam). The shearing of the working fluid results in the generation of a mist formed from droplets of substantially uniform size. A method of generating a mist in this manner is also disclosed.

An Improved Mist Generating Apparatus and Method

The present invention relates to the field of mist generating apparatus. More specifically, the invention is directed to an improved apparatus and method for generating liquid droplet mists.

5 Mist generating apparatus are known and are used in a number of fields. For example, such apparatus are used in both fire suppression and cooling applications, where the liquid droplet mists generated are more effective than a conventional fluid stream. Examples of such mist generating apparatus can be found in WO2005/082545 and
10 WO2005/082546 to the same applicant.

A problem with conventional mist generating apparatus is that not all of the working fluid being used is atomised as it passes through the apparatus. Although the majority of the working fluid is atomised upon entry into the
15 mixing chamber of the apparatus, some fluid is pulled into the chamber but is not atomised. The non-atomised fluid can stick to the wall of the mixing chamber and flow downstream along the wall to the outlet nozzle, where it can fall into the atomised fluid stream. This can cause the creation of droplets which are of non-uniform size. These droplets can then coalesce
20 with other droplets to create still larger droplets, thus increasing the problem and creating a mist of non-uniform droplets.

In cooling applications in particular, the uniformity of the size of the droplets in the mist is important. In turbine cooling applications, for
25 example, droplets which are over 10µm in diameter can cause significant damage to the turbine blades. It is therefore important to ensure control and uniformity of droplet size. Optimally sized droplets will evaporate, thus absorbing heat energy and increasing the air density in the turbine. This ensures that the efficiency of the turbine is improved. Existing turbine

cooling systems employ large droplet eliminators to remove large droplets and thus prevent damage to the turbine. However, such eliminators add to the complexity and manufacturing cost of the apparatus.

- 5 It is an aim of the present invention to obviate or mitigate one or more of the aforementioned disadvantages.

According to a first aspect of the present invention there is provided an apparatus for generating a mist, comprising:

- 10 an elongate hollow body; and
an elongate member co-axially located within the body such that a first transport fluid passage and a nozzle are defined between the body and the elongate member, the first transport fluid passage having a convergent-divergent internal geometry and being in fluid communication
15 with the nozzle;

- wherein the elongate member includes a working fluid passage and one or more communicating bores extending radially outwardly from the working fluid passage, the bores allowing fluid communication between the working fluid passage and the first transport fluid passage; and

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Preferably, the one or more communicating bores are substantially perpendicular to the first transport fluid passage.

- 25 Preferably, the communicating bore has an inlet connected to the working fluid passage and an outlet connected to the first transport fluid passage, the outlet having a greater cross-sectional area than the inlet.

- The body has an internal wall having an upstream convergent portion and a downstream divergent portion, the convergent and divergent portions at
30 least in part forming the convergent-divergent internal geometry of the first

working fluid passage. A first end of the elongate member has a cone-shaped projection, wherein the nozzle is defined between the divergent portion of the internal wall and the cone-shaped projection. The one or more communicating bores are adjacent the first end of the elongate member.

Preferably, the cone-shaped projection has a portion having an inclined surface rising from the surface of the cone.

10 In a first preferred embodiment, the elongate member further includes a second transport fluid passage having an outlet adjacent the tip of the cone-shaped projection. Preferably, the first and second transport fluid passages are substantially parallel. The second transport fluid passage preferably includes an expansion chamber.

15 In a second preferred embodiment, the bores allowing communication between the working fluid passage and the first transport fluid passage are first bores, and the body includes a second working fluid passage and one or more second communicating bores allowing fluid communication
20 between the second working fluid passage and the first transport fluid passage. Preferably, the second working fluid passage is located radially outward of the first working fluid passage and the first transport fluid passage. Preferably, the second bores are substantially perpendicular to the first transport fluid passage. Most preferably, the first and second
25 bores are co-axial.

In a third preferred embodiment, the elongate member further includes:
a second transport fluid passage located radially outward of the working fluid passage;

one or more first communicating bores extending radially outward from the working fluid passage, the first bores allowing fluid communication between the working fluid passage and the second transport fluid passage; and

5 one or more second communicating bores extending radially outward from the second transport fluid passage, the second bores allowing fluid communication between the second transport fluid passage and the first transport fluid passage;

10 wherein the first and second communicating bores are substantially perpendicular to the second and first transport fluid passages, respectively.

Preferably, the elongate member further includes a third transport fluid passage adapted to supply transport fluid into the second transport fluid passage adjacent the first and second communicating bores.

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Alternatively, the first transport fluid passage communicates with the nozzle via an outlet and a second transport fluid passage in fluid communication with the outlet, wherein the second transport fluid passage has a convergent-divergent internal geometry and is substantially perpendicular to the first transport fluid passage.

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As a further alternative, the apparatus further comprises a mixing chamber located between the first transport fluid passage and the nozzle, and a second transport fluid passage in communication with the mixing chamber and the first transport fluid passage, wherein the second transport fluid passage is adapted to supply transport fluid to the mixing chamber in a direction of flow substantially opposed to a direction of flow of transport fluid from the first transport fluid passage.

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According to a second aspect of the invention, there is provided a method of generating a mist, the method comprising the steps of:

supplying a working fluid through a working fluid passage;

5 supplying a first transport fluid through a first transport fluid passage;

forcing the working fluid from the working fluid passage into the first transport fluid passage via one or more communicating bores extending radially outward from the working fluid passage;

10 accelerating the first transport fluid upstream of the communicating bores so as to provide a high velocity transport fluid flow; and

applying the high velocity transport fluid flow to the working fluid exiting the communicating bores, thereby imparting a shear force on the working fluid and atomising the working fluid to produce a dispersed droplet flow regime.

15

Preferably, the high velocity transport fluid flow is applied substantially perpendicular to the working fluid flow exiting the bores.

20

Preferably, the step of accelerating the first transport fluid is achieved by providing the first transport fluid passage with a convergent-divergent internal geometry and forcing the first transport fluid through the convergent-divergent portion.

Preferably, the method further includes the steps of:

25

forcing the atomised working fluid from the first transport fluid passage into a second transport fluid passage via one or more second communicating bores extending radially outwardly from the first transport fluid passage;

30 supplying a second transport fluid through the second transport fluid passage;

accelerating the second transport fluid upstream of the second communicating bores so as to provide a second high velocity transport fluid flow; and

5 applying the second high velocity transport fluid flow to the atomised working fluid exiting the second communicating bores, thereby imparting a second shear force on the atomised working fluid and further atomising the working fluid.

10 Preferably, the second high velocity transport fluid flow is applied substantially perpendicular to the atomised working fluid flow exiting the second bores.

Preferred embodiments of the present invention will be described, by way of example only, with reference to the accompanying drawings, in which:
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Figures 1(a)-1(e) show detail section views of a first embodiment of a mist generating apparatus and potential modifications thereto;

Figure 2 shows a detail section view of a second embodiment of a mist generating apparatus;

20 Figure 3 shows a section view of a third embodiment of a mist generating apparatus;

Figures 4(a)-4(c) show detail section views of a fourth embodiment of a mist generating apparatus and potential modifications thereto;

25 Figure 5 shows a detail section view of a fifth embodiment of a mist generating apparatus;

Figure 6 shows a detail section view of a sixth embodiment of a mist generating apparatus; and

Figure 7 shows a detail section view of a seventh embodiment of a mist generating apparatus.

In this specification the terms “convergent”, “divergent” and “convergent-divergent” have been used to describe portions of components which define passages, as well as to describe the internal geometry of the passages themselves. A “convergent” portion or section reduces the cross sectional area of a passage, whilst a “divergent” portion or section increases the cross-sectional area of a passage. A passage having “convergent-divergent” internal geometry is a passage whose cross-sectional area reduces to form a throat section before increasing again.

Figure 1(a) shows a first embodiment of a mist generating apparatus according to the present invention. The apparatus, generally designated 10, comprises an elongate hollow body 12 which is preferably cylindrical and an elongate member 14 projecting co-axially within the body 12. The member 14 and body 12 are so arranged that a first transport fluid passage 16 and a nozzle 32 are defined between the two. The body 12 has an internal wall 18 which includes a convergent portion 20 upstream of a divergent portion 22. The elongate member 14 has an external wall 24 which is substantially straight and parallel to the longitudinal axis L shared by the body and elongate member. As Figure 1(a) is only a detail view, it will be appreciated that the entire apparatus is not illustrated in this figure. As the body 12 is generally cylindrical, a further portion of the body 12, mirrored about the longitudinal axis L, is present below the elongate member 14, but is not shown in Figure 1(a) for reasons of clarity. Thus, the body 12 and passage 16 surround the elongate member 14. The elongate member 14 ends in a cone-shaped projection 15 at the remote end thereof.

The elongate member 14 includes a passage 26 for the introduction of a working fluid. The passage will therefore be referred to as the working fluid passage 26. The passage 26 extends along the length of the

elongate member 14 and is also co-axial with the body 12 and elongate member 14. The passage 26 is blind, in that it ends in a cavity 28 located in the cone 15 of the elongate member 14. Extending radially outward from the passage 26, and preferably in a direction substantially perpendicular to the transport fluid passage 16, are one or more communicating bores 30. These bores 30 allow fluid communication between the working fluid passage 26 and the transport fluid passage 16. The cone 15 of the elongate member 14 and the divergent portion 22 of the internal wall 18 define a mixing chamber 19 which opens out into a nozzle 32 through which fluid is sprayed.

The operation of the first embodiment will now be described. A working fluid, such as water for example, is introduced from a working fluid inlet (not shown) into the working fluid passage 26. The working fluid flows along the passage 26 until reaching the cavity 28. Upon reaching the cavity 28, the working fluid is forced under pressure through the bores 30 into the transport fluid passage 16. A transport fluid, such as steam for example, is introduced from a transport fluid inlet (not shown) into the transport fluid passage 16. Due to the convergent-divergent section of the passage 16 formed by the convergent and divergent portions 20,22 of the body 18, the transport fluid passage 16 acts as a venturi section, accelerating the transport fluid as it passes through the convergent-divergent section into the mixing chamber 19. This acceleration of the transport fluid ensures that the transport fluid flows past the ends of the bores 30 at very high, possibly even supersonic, velocity.

With the transport fluid flowing at high velocity and the working fluid exiting the bores 30 into the passage 16, the working fluid is subjected to very high shear forces by the transport fluid as it exits the bores 30. Droplets are sheared from the working fluid flow, producing a dispersed droplet flow

regime. The atomised flow is then carried from the mixing chamber 19 to the nozzle 32. In such a manner, the apparatus 10 creates a flow of substantially uniform sized droplets from the working fluid.

5 Figures 1(b)-1(e) show examples of potential modifications to the bores 30. Figures 1(b)-1(d) show bores 30 where the bore outlet has a greater cross-sectional area than the bore inlet 29 communicating with the working fluid passage 26. In Figure 1(b) the bore 30 has a curved outward taper at the outlet 31b which provides the outlet 31b with a bowl-shaped
10 profile when viewed in section. In Figure 1(c), a similar arrangement is shown, but here the expanded diameter of the outlet 31c is achieved by providing a stepped portion rather than a gradual outward taper. With the nozzle of Figure 1(d), the bore 30 gradually tapers outwards along the length thereof from inlet 29 to outlet 31d.

15 By providing bores 30 whose outlets 31b,31c,31d are of greater diameter than their respective inlets 29, an area of lower pressure is provided in the working fluid as it leaves the outlets 31b,31c,31d. This has the effect of presenting a greater surface area of working fluid to the transport fluid in the mixing chamber 19, thereby further increasing the shear effect of the
20 transport fluid on the working fluid. Additionally, the expansion of the bores 30, particularly in the cases of the Figure 1(b) and 1(c) nozzles, will increase the turbulence of the working fluid flow as it exits the bores 30, limiting the potential for any of the working fluid flow to become trapped
25 along the walls of the bores 30.

As explained above, one undesirable phenomenon in mist generating apparatus is that some of the working fluid is not instantly atomised upon exit from the bores 30. In such instances, the non-atomised fluid can flow
30 along the wall of the cone 15 in the nozzle 32 and then disrupt the size of

the working fluid droplets which have already been atomised. This phenomenon can be avoided in the modified nozzle shown in Figure 1(e). With this nozzle, the wall of the cone 15 is provided with a portion 34 having an inclined surface rising upwardly from the surface of the cone 15 to a peak, also known as a surface separation point. Any non-atomised fluid flow along the cone 15 will flow up the inclined portion 34. Once the fluid flow arrives at the peak, it will be subjected to the shear forces of the transport fluid, causing it to atomise, and then join the remainder of the droplets as they exit the nozzle 32.

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Figure 2 shows a second embodiment of the apparatus, which also solves the same problem as the modified nozzle of Figure 1(e). In this instance, the elongate member 14 includes a working fluid passage 26 as before. However, instead of passing through the central axis of the elongate member 14 as in the previously described embodiments, in this embodiment the working fluid passage 26 is arranged so as to surround a second transport fluid passage 40 located along the longitudinal axis of the elongate member 14. The second transport fluid passage has an outlet 42 at the tip of the cone 15. The purpose of the second transport fluid passage 40 is to ensure any non-atomised fluid which flows down the outer surface of the cone 15 is atomised when it reaches the outlet 42 of the second transport fluid passage 40. Thus, transport fluid flows through both the first transport fluid passage 16 and the second transport fluid passage 40. The second transport fluid passage 40 can include an expansion chamber 44 if desired, and is preferably substantially parallel to the first transport fluid passage 16.

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A third embodiment of the apparatus is shown in Figure 3. This embodiment shares a number of features with the first embodiment described above. As a result, these features will not be described again in

detail here, but have been assigned the same reference numbers, where appropriate. The first difference between the first and third embodiments is that the external wall 24' of the elongate member 14 is of the same convergent-divergent geometry as the internal wall 18 of the body 12.

5 Hence, the convergent and divergent portions 20,22 of the internal wall 18 are mirrored by identical portions of the external wall 24' of the elongate member 14. As a result, both walls 18,24' define a throat section 50 in the first transport fluid passage 16.

10 The second difference between the third embodiment of the apparatus and the preceding embodiments is that as well as having a first working fluid passage 26 along the centre of the elongate member 14, a second working fluid passage 52 is also provided in the body 12, the second working fluid passage 52 surrounding both the first working fluid passage
15 26 and the transport fluid passage 16 such that it is located radially outward thereof. This means that working fluid is supplied into the mixing chamber 19 from both first and second bores 30,54 which extend radially outward from their respective passages 26,52 and connect the first and second working fluid passages 26,52 with the transport fluid passage 16.
20 As with the first working fluid passage 26, the second working fluid passage 52 is also blind, with a cavity 56 located at the end of the passage 52 remote from the working fluid inlet (not shown). The first and second bores 30,54 are preferably co-axial, as seen in section in Figure 3. This ensures that the working fluid enters the transport fluid passage 16 at
25 the same point from both the first and second working fluid passages 26,52. The first and second bores 30,54 are also preferably perpendicular to the transport fluid passage 16.

The third embodiment will operate in substantially the same manner as
30 that described in respect of the first embodiment. Working fluid exiting the

first and second bores 30,54 under pressure will be sheared by the transport fluid flowing through the transport fluid passage 16, thereby creating a mist of uniform sized droplets.

5 A fourth embodiment of the invention is illustrated in Figure 4(a). Again, the basic layout of the apparatus is the same as with the first embodiment, so like features have been again assigned the same reference numbers. The elongate member 14 has a central working fluid passage 26 which ends in a cavity 28 remote from a working fluid inlet (not shown). A first
10 transport fluid passage 16 is defined by an external wall 24 of the elongate member 14 and convergent and divergent portions 20,22 of the internal wall 18 of the body 12. Again, it will be appreciated that Figure 4(a) only illustrates half of the apparatus, with the half not illustrated being a mirror image about the longitudinal axis L of the illustrated portion. The first
15 transport fluid passage 16 surrounds the elongate member 14

The elongate member 14 of this fourth embodiment is adapted to include a second transport fluid passage 60 located radially outward of the central working fluid passage 26. The transport and working fluid passages 60,26
20 are co-axial about the longitudinal axis L. With the second transport fluid passage 60 surrounding the working fluid passage 26, the second transport fluid passage 60 lies between the working fluid passage 26 and the first transport fluid passage 16. A number of first bores 62 allow fluid communication between the working fluid passage 26 and the second
25 transport fluid passage 60. A number of second bores 64 allow fluid communication between the second transport fluid passage 60 and the first transport fluid passage 16.

In operation, working fluid is forced through the first bores 62 under
30 pressure into the second transport fluid passage 60, where transport fluid

shears the working fluid as it enters the second transport fluid passage. The resultant atomised fluid is then forced through the second bores 64 into the first transport fluid passage 16, whereupon it is sheared for a second time by a second flow of transport fluid. Providing two locations at
5 which the working fluid is subjected to the shear forces of the transport fluid allows the apparatus to generate still smaller droplet sizes.

Figures 4(b) and 4(c) illustrate examples of communicating bores 70,72 which are not perpendicular to the flow of transport fluid through the
10 transport fluid passage 16. The bore 70 of Figure 4(b) presents fluid into the transport fluid flow at an angle of less than 90 degrees such that the fluid flows against the flow of transport fluid. Such an arrangement increases the shear forces on the working fluid from the transport fluid. In Figure 4(c) the bore 72 is at an angle of over 90 degrees, so that the fluid
15 flow is at an angle to the transport fluid flow, but is not perpendicular thereto. This arrangement reduces the amount of shear imparted on the working fluid by the transport fluid.

A fifth embodiment of the invention is illustrated in Figure 5. The elongate
20 member 14 has a central working fluid passage 26 which ends in a cavity 28 remote from a working fluid inlet (not shown). A first transport fluid passage 16 is defined by an external wall 24 of the elongate member 14 and convergent and divergent portions 20,22 of the internal wall 18 of the body 12. In this embodiment, the external wall 24 of the elongate member
25 14 tapers outwardly towards the body 12 in the direction of flow until it reaches one or more second bores 64. Again, it will be appreciated that Figure 5 only illustrates half of the apparatus, with the half not illustrated being a mirror image about the longitudinal axis L of the illustrated portion.

The elongate member 14 of this fourth embodiment is adapted to include a second transport fluid passage 60 located radially outward of the central working fluid passage 26. The transport and working fluid passages 60,26 are co-axial about the longitudinal axis L. With the second transport fluid passage 60 surrounding the working fluid passage 26, the second transport fluid passage lies radially between the working fluid passage 26 and the first transport fluid passage 16. One or more first bores 62 allow fluid communication between the working fluid passage 26 and the second transport fluid passage 60. One or more of the second bores 64 allow fluid communication between the second transport fluid passage 60 and the first transport fluid passage 16.

A further difference between the fifth embodiment and the preceding fourth embodiment in particular is that a third transport fluid passage 80 is provided in the elongate member 14. The third transport fluid passage 80 may receive transport fluid from the same source as the first and second transport fluid passages 16,60, or else it may have its own dedicated transport fluid source (not shown). The third transport fluid passage 80 has an outlet 82 which is adjacent the outlet(s) of the first bore(s) 62. As a result, the outlets of the second and third transport fluid passages 60,80 are positioned either side of the first bores 62 and open into the second bores 64.

In operation, working fluid is forced through the first bores 62 under pressure from the working fluid passage 26, where transport fluid from the second and third transport fluid passages 60,80 shears the working fluid. The resultant atomised fluid then flows through the second bores 64 into the first transport fluid passage 16, whereupon it is sheared for a second time by a second flow of transport fluid. Providing two locations at which the working fluid is subjected to the shear forces of the transport fluid

allows the apparatus to generate still smaller droplet sizes. By providing two sources of transport fluid from the second and third transport fluid passages 60,80 adjacent the first bore(s) 62, even smaller droplets of the working fluid can be obtained due to the effective twin shear action of the transport fluid on the working fluid prior to the atomised fluid entering the second bore(s) 64 and being further atomised.

Figures 6 and 7 show sixth and seventh embodiments of the apparatus, respectively, in which secondary shear actions take place in the manner of the fourth and fifth embodiments described above. In the sixth embodiment shown in Figure 6, the elongate member 14 has a working fluid passage 26 which ends in a cavity 28 remote from a working fluid inlet (not shown). A first transport fluid passage 16 is defined by an external wall 24 of the elongate member 14 and convergent and divergent portions 20,22 of the internal wall 18 of the body 12. The external wall 24 of the elongate member 14 runs substantially parallel to the transport fluid passage 26. One or more first bores 62 allow fluid communication between the working fluid passage 26 and the first transport fluid passage 16.

The key difference between the sixth embodiment and the fifth embodiment in particular is that a second transport fluid passage 90 is provided, but in this case the second transport fluid passage 90 is substantially perpendicular to the first transport fluid passage 16. The second transport fluid passage 90 may receive transport fluid from the same source as the first transport fluid passage 16, or else it may have its own dedicated transport fluid source (not shown). In this embodiment, the first transport fluid passage 16 has an outlet 17 in communication with the second transport fluid passage 90. A mixing chamber 19 is defined where the first and second transport fluid passages 16,90 meet one another.

The second transport fluid passage 90 has a convergent-divergent internal geometry upstream of the first transport fluid passage outlet 17, thereby ensuring that the transport fluid passing through the passage 90 is accelerated prior to meeting the atomised fluid exiting the first transport fluid passage 16.

In operation, working fluid is forced through the first bores 62 from the working fluid passage 26, where transport fluid from the first transport fluid passage 16 shears the working fluid. The resultant atomised fluid then flows through the outlet 17 into the second transport fluid passage 90, whereupon it is sheared for a second time by the second flow of transport fluid.

The seventh embodiment of the invention differs from the sixth embodiment in that the second transport fluid passage 100 is arranged such that the direction of the second transport fluid flow is generally opposite to the flow of transport fluid through the first transport fluid passage 16. As before, both the first and second transport fluid passages 16,100 have convergent-divergent internal geometry.

Working fluid exits the working fluid passage 26 via first bore(s) 62 in a flow direction preferably perpendicular to the first transport fluid passage 16. Transport fluid accelerated through the passage 16 shears the working fluid exiting the bore(s) 62, creating an atomised fluid flow. The atomised fluid flow, flowing in the direction indicated by arrow D1, then meets the accelerated opposing secondary transport fluid flow, illustrated by arrow D2, at a mixing chamber 19. The two fluid flows D1,D2 collide in the mixing chamber 19 to further atomise the working fluid prior to the atomised working fluid exiting via outlet 104.

The purpose of the sixth and seventh embodiments is to shear the working fluid once and then carry the droplets into a further stream of transport fluid where the velocity of the droplets is reduced. This allows the production of uniform droplets by shearing with a first, preferably
5 supersonic, stream of transport fluid and then reducing the velocity of the stream with the second transport fluid flow. These embodiments are for use in applications which require small droplet size but low projection velocities.

10 Each of the embodiments described here preferably uses a generally perpendicular arrangement of the working fluid bores and transport fluid passages to obtain a crossflow of the transport and working fluids. This crossflow (where the two fluid flows meet at approximately 90 degrees to one another) ensures the penetrative atomisation of the working fluid as
15 the transport fluid breaks up the working fluid. The natural Kelvin-Helmholtz/Rayleigh Taylor instabilities in the working fluid as it is forced into an ambient pressure environment also assist the atomisation of the working fluid.

20 Furthermore, by locating the elongate member 14 along the centre of the apparatus, the atomised working fluid exits the apparatus via an annular nozzle which surrounds the elongate member. The elongate member creates a low pressure recirculation zone adjacent the cone 15. As the high-speed atomised working fluid exits the annular nozzle it imparts
25 further shear forces on the droplets in the recirculation zone, leading to a further atomisation of the working fluid.

In the fifth embodiment shown in Figure 5, the method of operation may be adapted by swapping the functions of the fluid passages 26,60,80. In
30 other words, the passage 26 could supply the transport fluid, whilst the

passages 60,80 supply the working fluid. In an alternative adaptation of the apparatus of the fifth embodiment, the apparatus could be adapted to feed gas bubbles through the first bores 62 as the working fluid passes through. This has the effect of breaking up the working fluid stream prior to atomisation and also increasing turbulence in the working fluid, both of which help improve the atomisation of the working fluid in the apparatus.

Further modifications and improvements may be incorporated without departing from the scope of the invention.

CLAIMS:

1. An apparatus for generating a mist, comprising:
an elongate hollow body; and
5 an elongate member located within the body such that a first transport fluid passage and a nozzle are defined between the body and the elongate member, the first transport fluid passage having a convergent-divergent internal geometry and being in fluid communication with the nozzle;
10 wherein the elongate member includes a working fluid passage and one or more communicating bores extending radially outwardly from the working fluid passage, the bores allowing fluid communication between the working fluid passage and the first transport fluid passage.
- 15 2. The apparatus of Claim 1, wherein the one or more communicating bores are substantially perpendicular to the first transport fluid passage.
3. The apparatus of either Claim 1 or Claim 2, wherein the communicating bores have an inlet connected to the working fluid passage
20 and an outlet connected to the first transport fluid passage, the outlet having a greater cross-sectional area than the inlet.
4. The apparatus of any preceding claim, wherein the body has an internal wall having an upstream convergent portion and a downstream
25 divergent portion, the convergent and divergent portions at least in part forming the convergent-divergent internal geometry of the first working fluid passage.
5. The apparatus of Claim 4, wherein a first end of the elongate
30 member has a cone-shaped projection, wherein the nozzle is defined

between the divergent portion of the internal wall and the cone-shaped projection.

5 6. The apparatus of Claim 5, wherein the cone-shaped projection has a portion having an inclined surface rising from the surface of the cone.

10 7. The apparatus of either Claim 5 or Claim 6, wherein the elongate member further includes a second transport fluid passage having an outlet adjacent the tip of the cone-shaped projection.

8. The apparatus of Claim 7, wherein the second transport fluid passage includes an expansion chamber.

15 9. The apparatus of any of Claims 1 to 6, wherein the bores allowing communication between the working fluid passage and the first transport fluid passage are first bores, and the body includes a second working fluid passage and one or more second communicating bores allowing fluid communication between the second working fluid passage and the first transport fluid passage, wherein the second working fluid passage is
20 located radially outward of the first working fluid passage and the first transport fluid passage.

25 10. The apparatus of Claim 9, wherein the second bores are substantially perpendicular to the first transport fluid passage.

11. The apparatus of either Claim 9 or Claim 10, wherein the first and second bores are co-axial.

30 12. The apparatus of any of Claims 1 to 6, wherein the elongate member further includes:

a second transport fluid passage located radially outward of the working fluid passage;

5 one or more first communicating bores extending radially outward from the working fluid passage, the first bores allowing fluid communication between the working fluid passage and the second transport fluid passage; and

10 one or more second communicating bores extending radially outward from the second transport fluid passage, the second bores allowing fluid communication between the second transport fluid passage and the first transport fluid passage;

wherein the first and second communicating bores are substantially perpendicular to the second and first transport fluid passages, respectively.

15 13. The apparatus of Claim 12, wherein the elongate member further includes a third transport fluid passage adapted to supply transport fluid into the second transport fluid passage adjacent the first and second communicating bores.

20 14. The apparatus of any of Claims 1 to 4, wherein the first transport fluid passage communicates with the nozzle via an outlet and a second transport fluid passage in fluid communication with the outlet, wherein the second transport fluid passage has a convergent-divergent internal geometry and is substantially perpendicular to the first transport fluid
25 passage.

15. The apparatus of any of Claims 1 to 4, further comprising a mixing chamber located between the first transport fluid passage and the nozzle, and a second transport fluid passage in communication with the mixing
30 chamber and the first transport fluid passage, wherein the second

transport fluid passage is adapted to supply transport fluid to the mixing chamber in a direction of flow substantially opposed to a direction of flow of transport fluid from the first transport fluid passage.

- 5 16. A method of generating a mist, the method comprising the steps of:
 supplying a working fluid through a working fluid passage;
 supplying a first transport fluid through a first transport fluid
 passage;
 forcing the working fluid from the working fluid passage into the first
10 transport fluid passage via one or more communicating bores extending
 radially outward from the working fluid passage;
 accelerating the first transport fluid upstream of the communicating
 bores so as to provide a high velocity transport fluid flow; and
 applying the high velocity transport fluid flow to the working fluid
15 exiting the communicating bores, thereby imparting a shear force on the
 working fluid and atomising the working fluid to produce a dispersed
 droplet flow regime.
- 20 17. The method of Claim 16, wherein the high velocity transport fluid
 flow is applied substantially perpendicular to the working fluid flow exiting
 the bores.
- 25 18. The method of either Claim 16 or Claim 17, wherein the step of
 accelerating the first transport fluid is achieved by providing the first
 transport fluid passage with a convergent-divergent internal geometry and
 forcing the first transport fluid through the convergent-divergent portion.
19. The method of any of Claims 16 to 18, further comprising the steps
 of:

forcing the atomised working fluid from the first transport fluid passage into a second transport fluid passage via one or more second communicating bores extending radially outwardly from the first transport fluid passage;

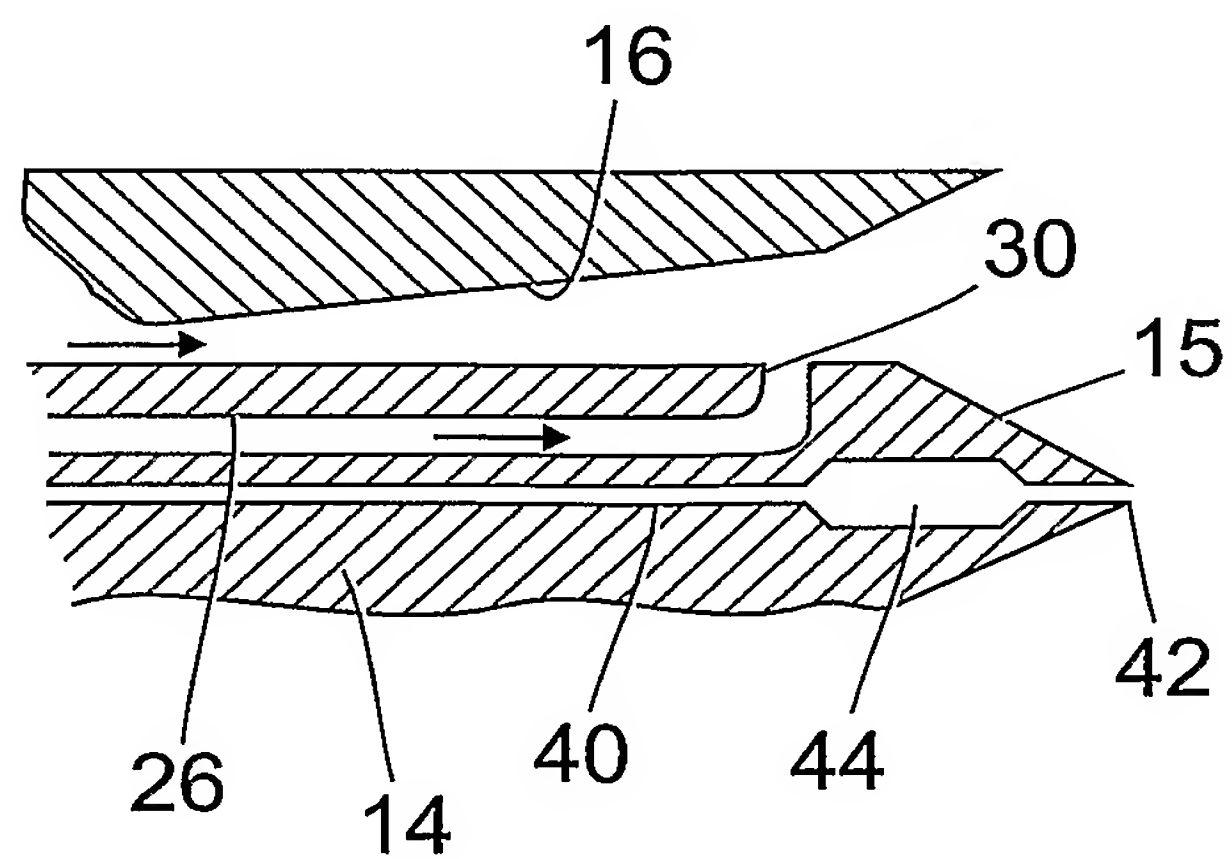
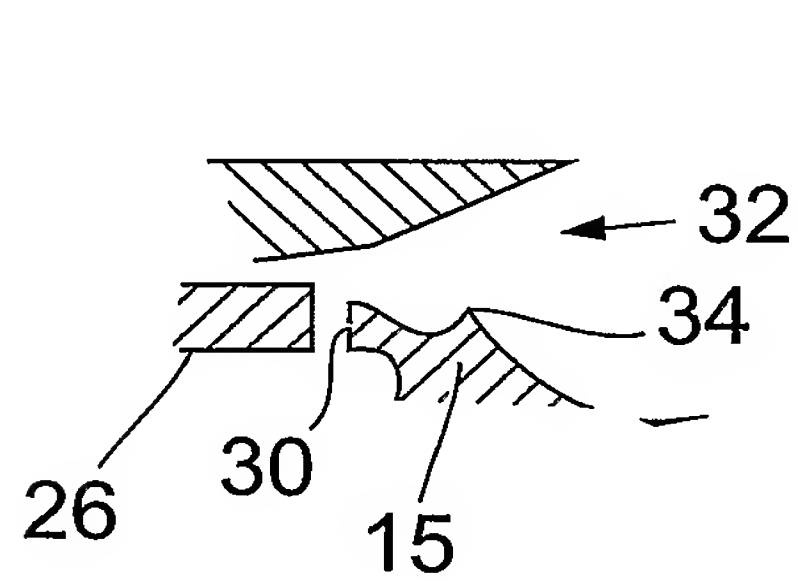
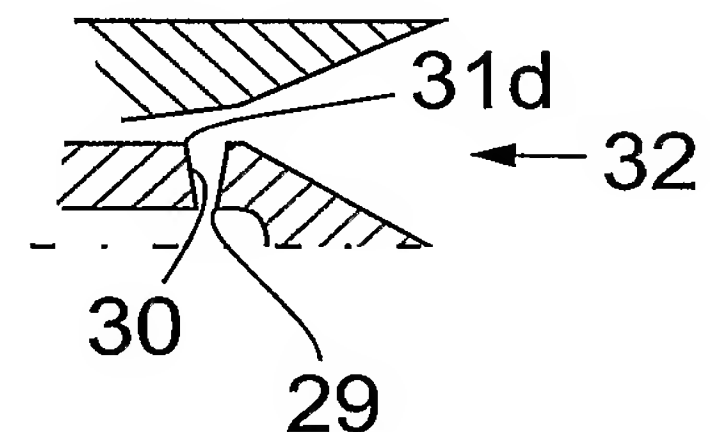
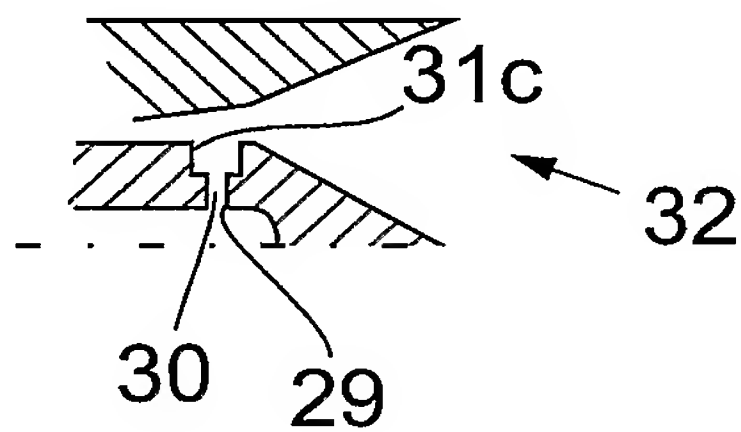
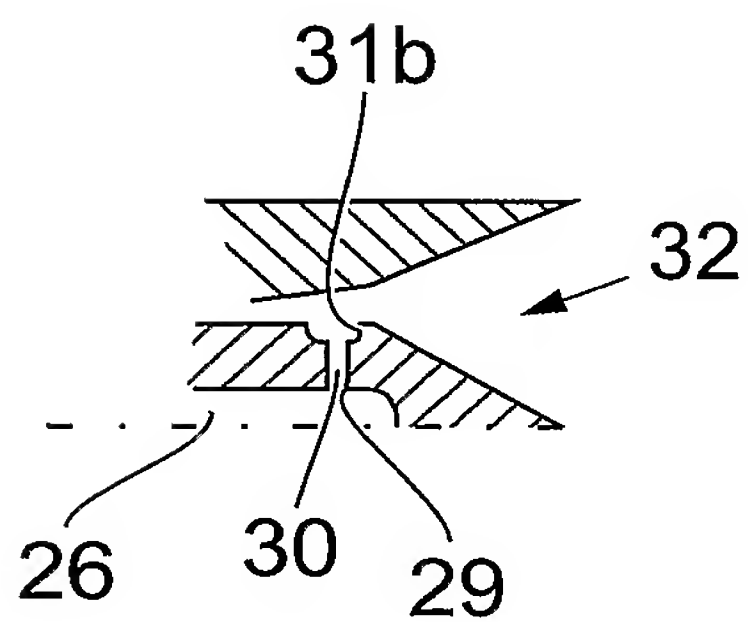
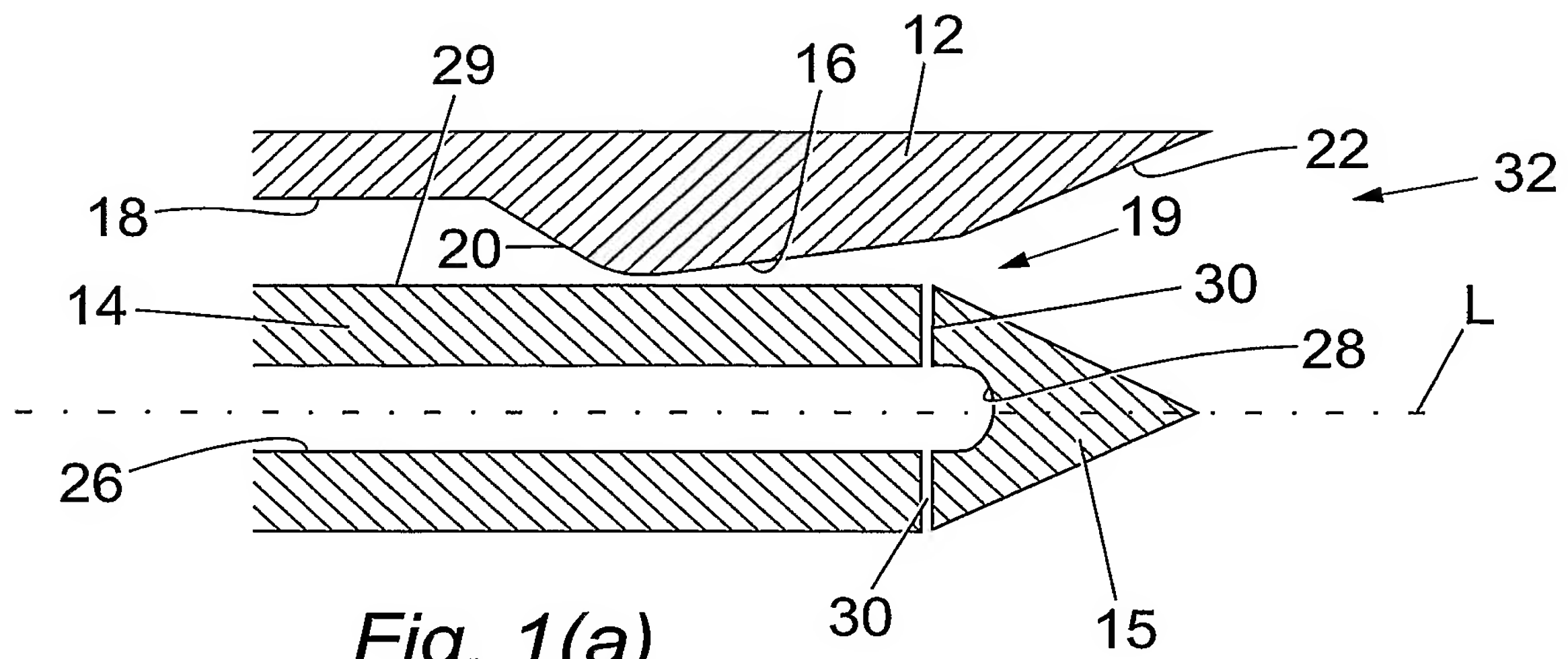
- 5 supplying a second transport fluid through the second transport fluid passage;

 accelerating the second transport fluid upstream of the second communicating bores so as to provide a second high velocity transport fluid flow; and

- 10 applying the second high velocity transport fluid flow to the atomised working fluid exiting the second communicating bores, thereby imparting a second shear force on the atomised working fluid and further atomising the working fluid.

- 15 20. The method of Claim 19, wherein the second high velocity transport fluid flow is applied substantially perpendicular to the atomised working fluid flow exiting the second bores.

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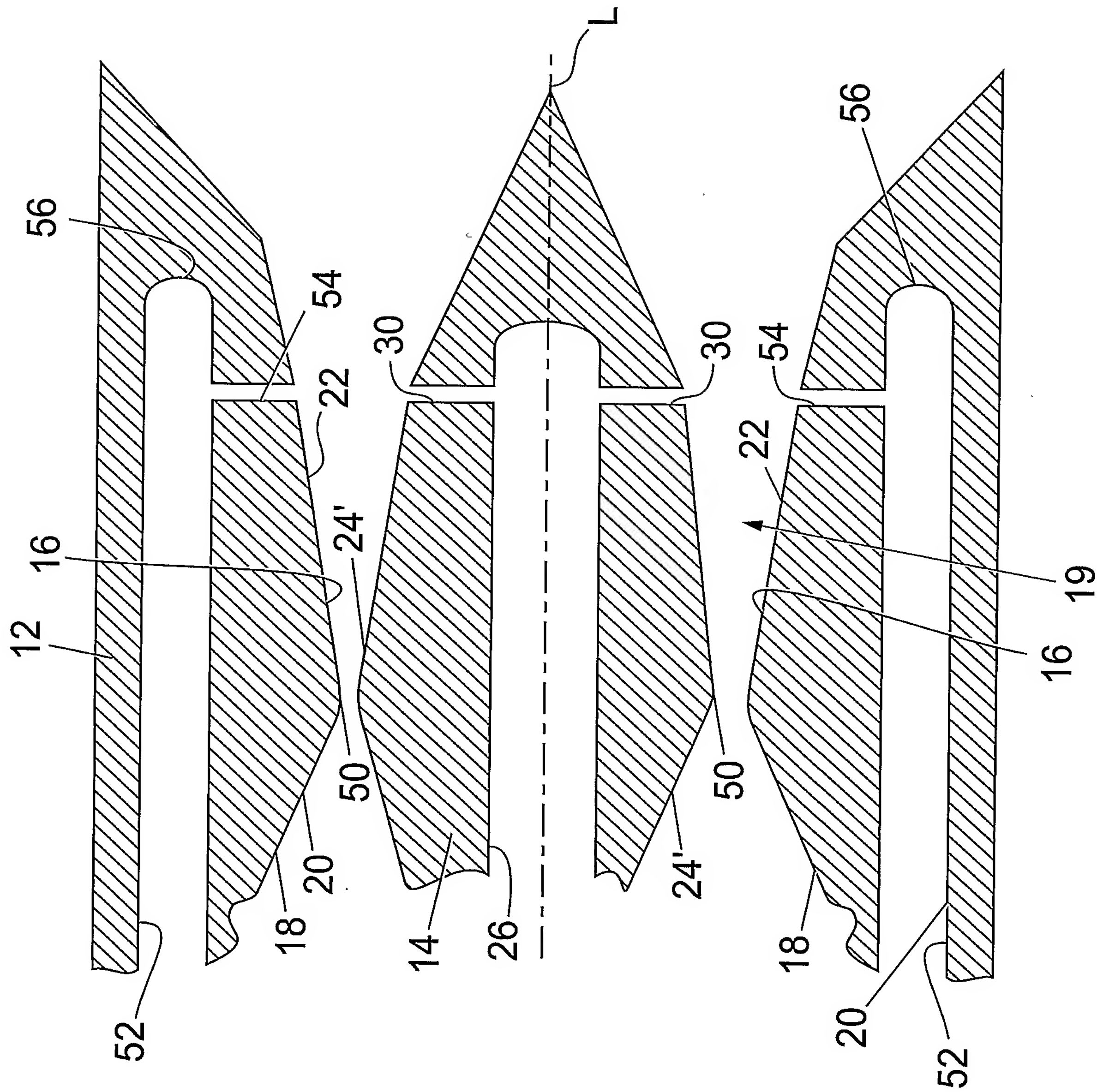
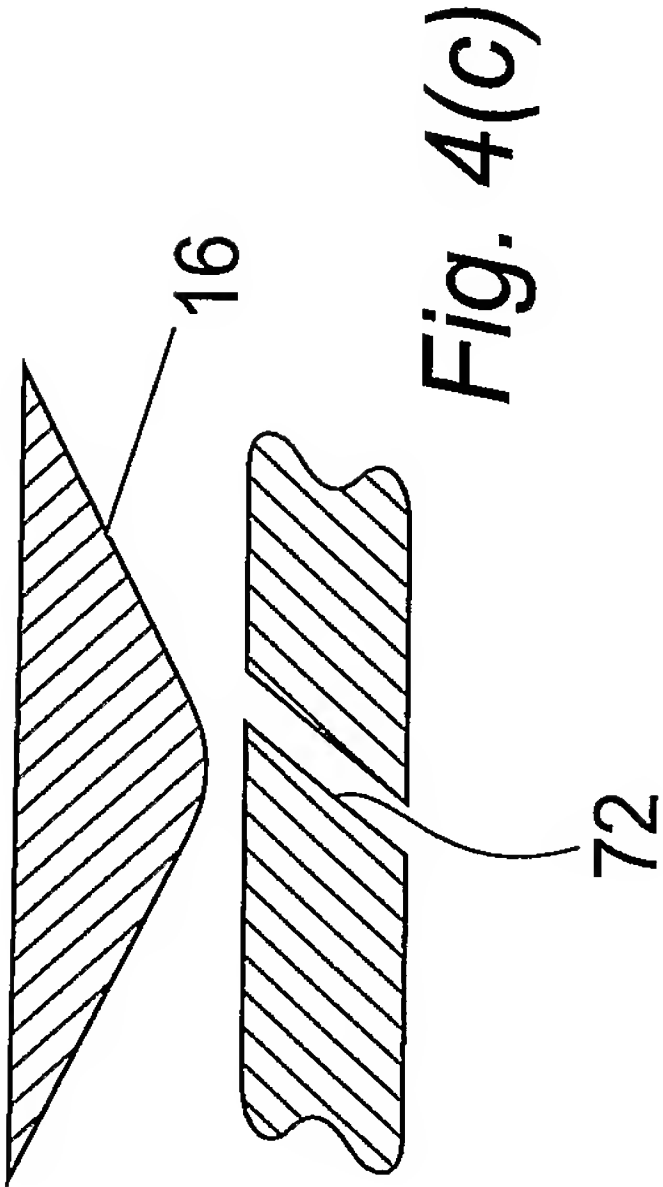
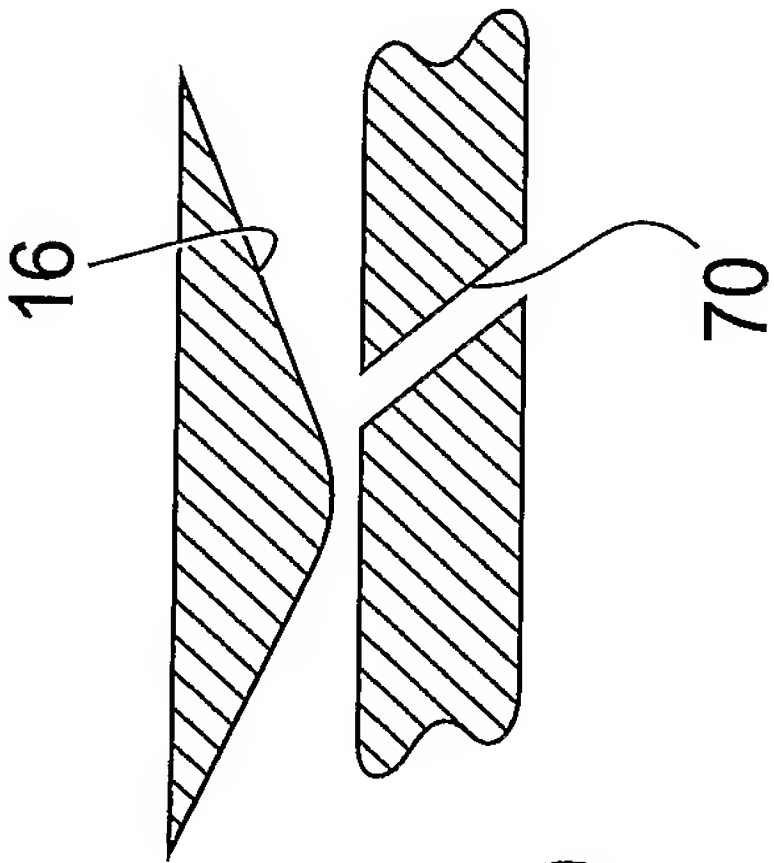
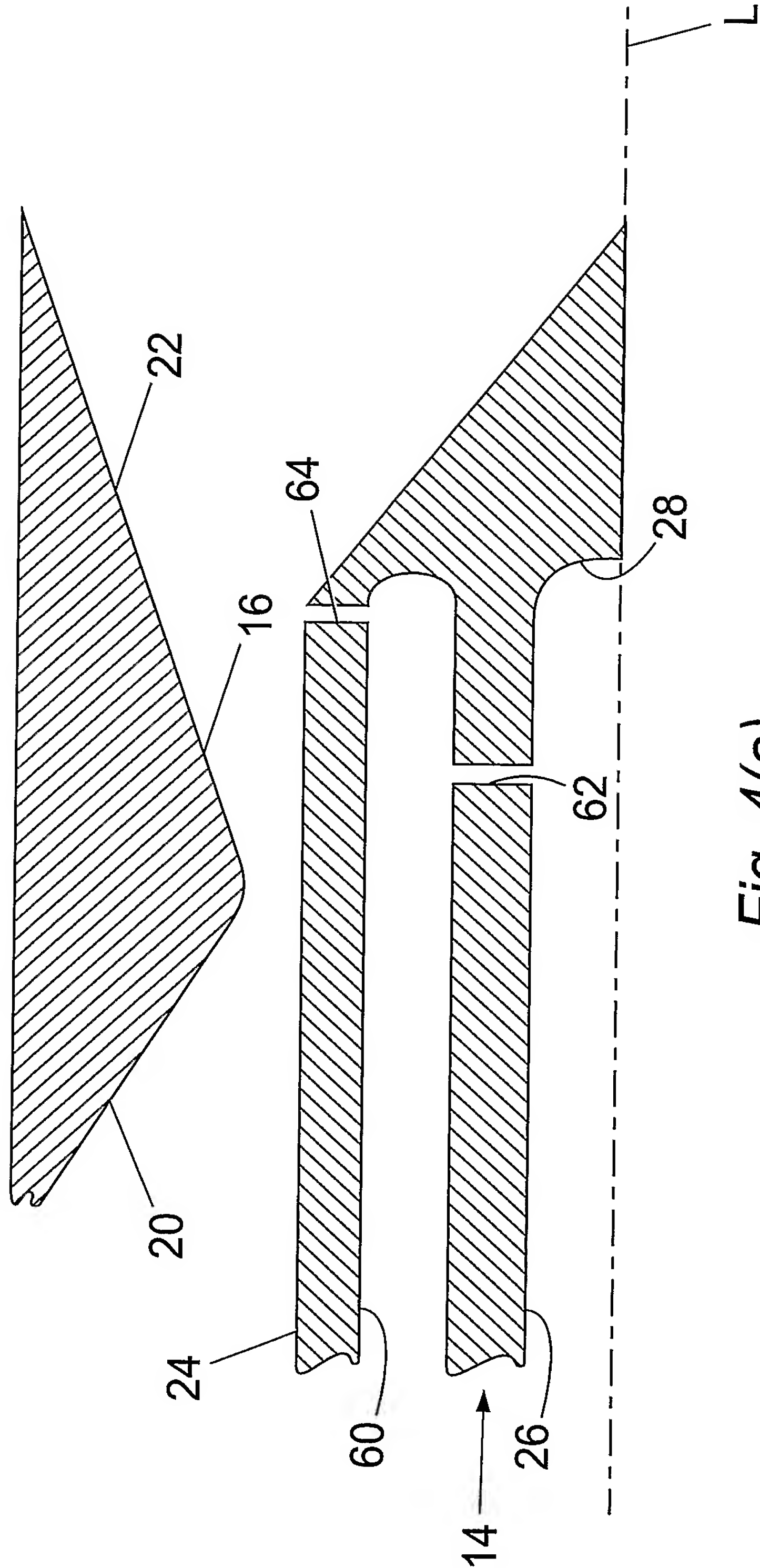


Fig. 3



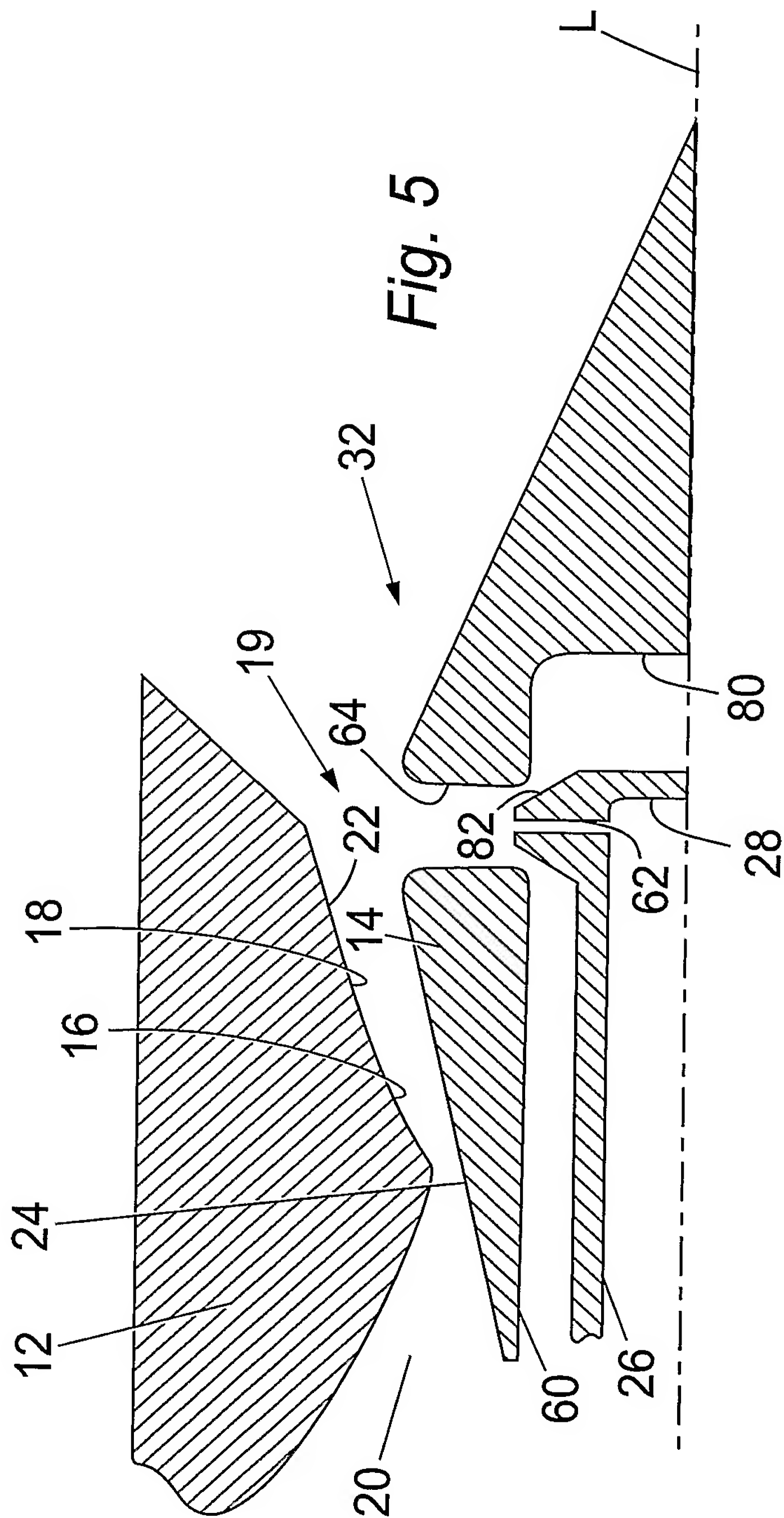


Fig. 5

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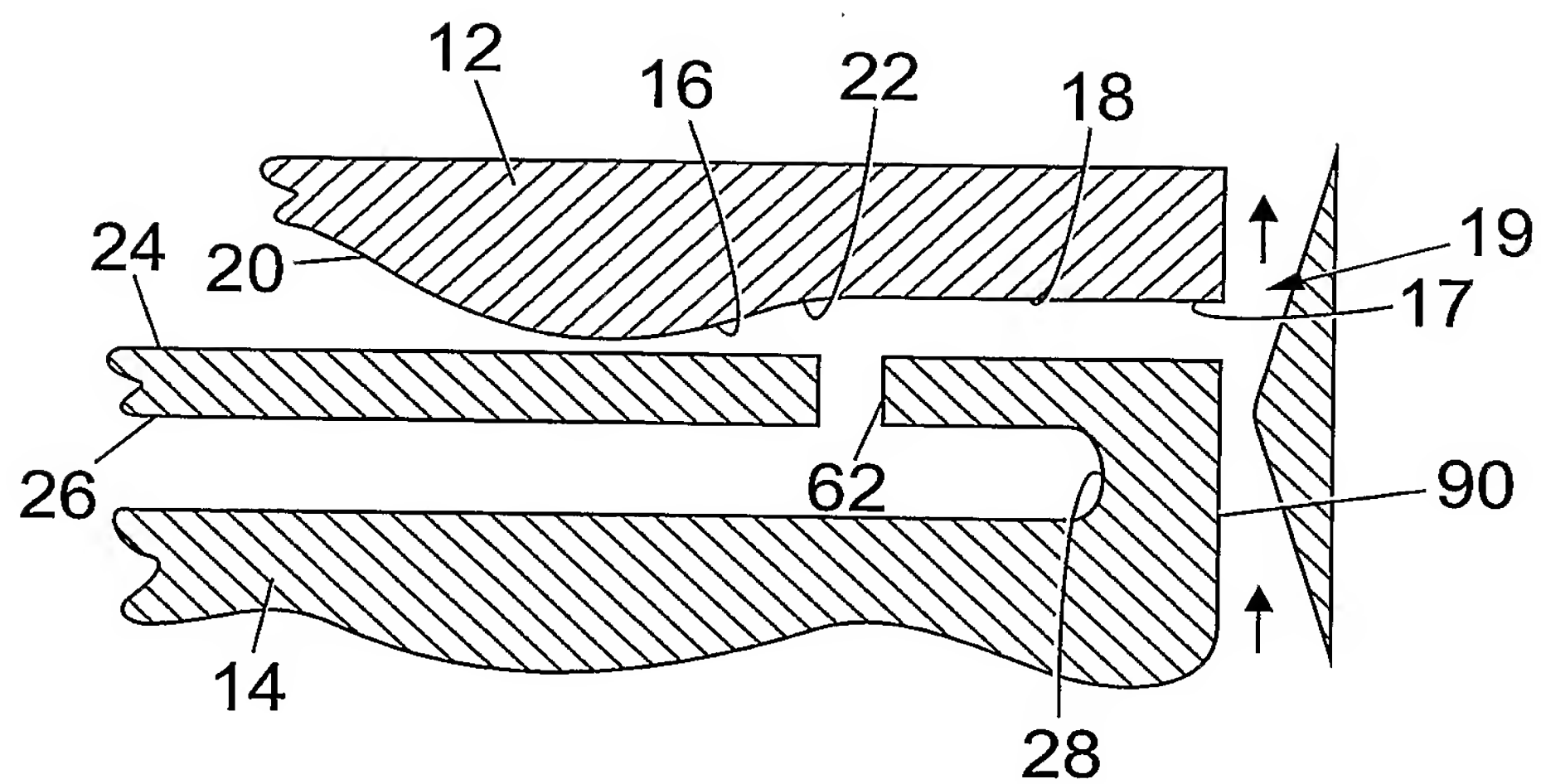


Fig. 6

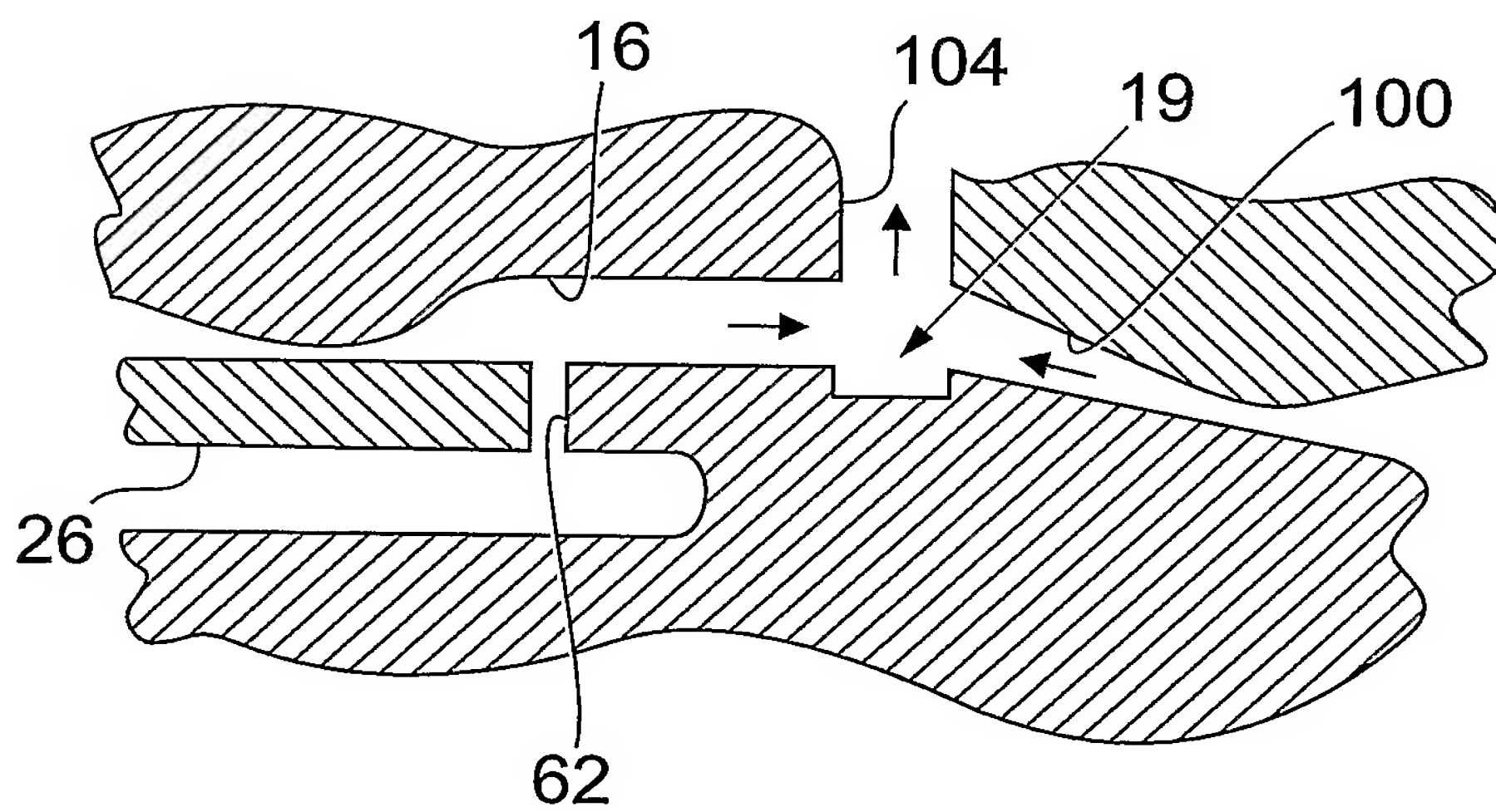


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2007/003492

A. CLASSIFICATION OF SUBJECT MATTER
INV. B05B7/04 A62C31/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B05B A62C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FR 1 354 965 A (S E M I A C SOC DE MATERIEL IN) 13 March 1964 (1964-03-13) figure 1 -----	1,2,4-6, 16-18
X	WO 01/76764 A (CHROBAK JULIUS [SK]) 18 October 2001 (2001-10-18) figure 1 -----	1,2,4, 16-18
X	US 5 860 598 A (CRUZ LUIS R [AR]) 19 January 1999 (1999-01-19) figure 3 -----	1,2,4, 16-18
X	US 2004/222317 A1 (HUFFMAN DAVID C [US]) 11 November 2004 (2004-11-11) figure 2 ----- -/--	1,2,4, 16-18



Further documents are listed in the continuation of Box C.



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Date of the actual completion of the international search

13 December 2007

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27/12/2007

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Roldán Abalos, Jaime

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2007/003492

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 252 298 A (JONES DALE G [US]) 12 October 1993 (1993-10-12) column 7, line 30 - line 50 figures 2,3 -----	1,2, 16-18
A	US 2006/102749 A1 (CRABTREE DENNIS W [US] ET AL) 18 May 2006 (2006-05-18) the whole document -----	1-20

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2007/003492

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
FR 1354965	A	13-03-1964	NONE		
WO 0176764	A	18-10-2001	CZ	20023443 A3	18-06-2003
			CZ	14882 U1	12-01-2005
			SK	5272000 A3	03-12-2001
US 5860598	A	19-01-1999	NONE		
US 2004222317	A1	11-11-2004	NONE		
US 5252298	A	12-10-1993	NONE		
US 2006102749	A1	18-05-2006	US	7140552 B1	28-11-2006